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Discharge features in a non-chain HF-laser

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Electric discharge parameters and amplitude-temporal and spectral parameters of laser radiation in gas mixtures of SF_6 with hydrogen and hydrocarbons are studied. High discharge uniformity obtained with the use of special shaped electrodes along with uniform UV preionization is key parameter for improving intrinsic efficiency of discharge HF-laser. Experimental conditions providing high intrinsic efficiency of a non-chain HF laser are determined.

1. Introduction

Lasers with non-chain chemical reaction excited by a self-sustained discharge are the most promising for many practical applications [1-7]. In certain experimental conditions high radiation parameters were obtained without preionization of the laser active volume [1,2]. The use of intense preionization allow us to obtain the same pulsed energy of HF laser using mixtures of SF_6 with hydrogen and hydrocarbons and it was suggested to use profilated electrodes for improving discharge stability and output parameters of non-chain chemical lasers [3]. Importance of preionization for efficient operation of HF laser was also demonstrated in [4,5]. In [3,6] intrinsic efficiency of a non-chain HF laser was improved using pulse generator with inductive energy storage. In the present paper, effects of preionization and pumping pulse parameters on output parameters of discharge HF laser are studied.

2. Experimental technique

The installation was similar to the long pulse excimer laser excited by the inductive energy storage with semiconductor opening switch [7]. The laser has active volume 2-3,8×0,6-1,4×70 cm^3 (discharge gap d = 2 or 3,8 cm). The active volume and cathode surface was uniformly preionized by 72 spark gaps evenly distributed along both sides of anode. Some experiments were made without preionization. Six SOS-50-2 diodes were used as the opening switch.

3. Discharge stability and HF laser output

Gas mixture of non-chain HF laser contains more than 70% of SF_6. However volume discharge in these mixtures is relatively easy to form. The laser action was obtained in wide range of gas mixture composition and pumping pulse parameters. Development of small-scale roughness on electrode surfaces (especially on cathode surface) improves conditions for volume discharge formation in gas mixtures with hydrocarbons without or at low intensity preionization. Therewith uniform electric field in the discharge gap of a laser on SF_6-hydrocarbone mixture is not necessary [4]. However, discharge in H_2-based mixtures is more sensitive to the preionization conditions and electric field strength in the laser gap. In our experiments, the laser output lower 0,2 J was obtained with the gap of d = 2 cm. Arc formation was evident 50-200 ns later the gap breakdown due to non-uniform electric field strength across the laser gap and on the cathode surface independently on the preionization parameters. Therefore further experiment were made with d = 3,8 cm and electrodes providing uniform electric field. Disconnection of preionization results in two – tree fold increase of the breakdown voltage. However, strong deterioration of discharge stability is evident in hydrogen based mixtures. At low pressure chaotically distributed anode and cathode flares with different length penetrate into the discharge volume and short down the gap, the laser output decreases by a factor of 1,5. The number of these arc channels in the laser gap increases with the mixture pressure accompanied by sharp increase of discharge current and 50-100 ns later the breakdown and further decrease of the laser output. The use of preionization removes anode flares and arcs from the laser volume and improve the laser output. However, large number cathode flares grows into the laser gap during current pulse.

In the case of gas mixtures with pentane preionization has much lower effect on the discharge quality. In both cases a large number of small bright spots on the cathode surface and very uniform discharge luminescence without any sign of arcing and minor difference of the laser output only at low U_0 are evident. In the absence of preionization discharge appears in several local points and than expands on full electrode surface, the time of discharge formation decreases at high U_0 resulting in lower energy losses during discharge formation [2]. Therefore the laser output was independent on preionization at U_0>30 kV. Additional indication of the discharge uniformity is partial discharge of the storage capacitor C_0 and residual voltage U_{res} is measured across the gap after the discharge current termination. U_{res} increases directly to the mixture pressure and inversely to the charging voltage. Maximal U_{res} was observed in the mixtures with H_2 (see Figure 1). Development of discharge non-uniformities results in zero U_{res}. At low pressure and high U_0 stored energy is totally deposited into the volume discharge (see Figure 2) and U_{res}=0, as well.

The use of the inductive generator and preionization similarly to [3,6] increases breakdown voltage by a

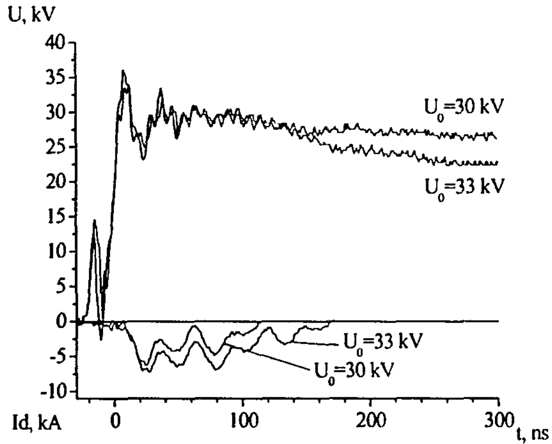

Figure 1: Voltage across the laser gap and discharge current in SF_6:H_2=60:7,5 Torr mixture.

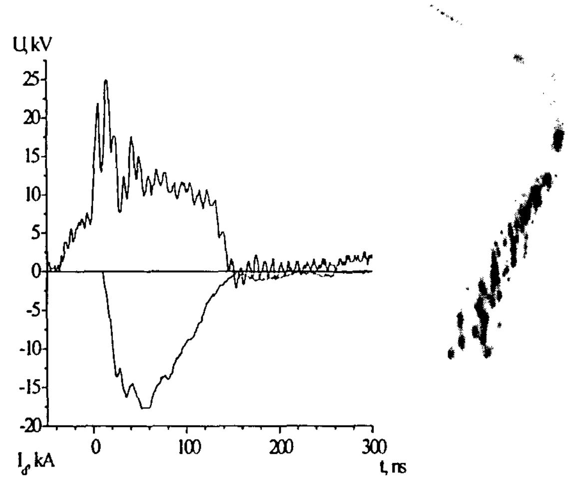

Figure 2: Waveforms of voltage across the laser gap and discharge current and discharge view (negative) in SF_6:H_2=24:3 Torr mixture. U_0=33 kV.

factor of 1,5-2, shortens rise-time of discharge current and in some conditions increases discharge current amplitude. In the case of the inductive generator U_{res} depends on the discharge resistance and is determined by recharging of capacitor C_p from C_0 during current pulse. Breakdown voltage up to 50-60 kV and 50-100 ns excitation pulse with current amplitude up to 30 kA was obtained with the inductive generator. It is important that considerable part of input energy is deposited into the laser active media at high *E/p* across the laser gap during voltage drop after the gap breakdown. As it is seen from Figure 2, the inductive generator improves discharge homogeneity. Similarly to pentane based mixtures highly uniform discharge fluorescence without cathode flares was observed in mixtures with H_2. Note that about half of the energy stored in C_0 is lost in SOS diodes during current interruption and remains in the C_p-L_p-C_0-L_0 circuit. With the use of preionization the laser output in H_2 based mixtures was close to that with the capacitor generator, and decreases in C_5H_{12} based mixtures. Without preionization the output decreases by a factor of about 2 for all mixtures with H_2.

The laser efficiency with respect to deposited energy up to η_{in} ~10 % is obtained using discharge excitation by the inductive and capacitor generators in the SF_6-H_2 mixtures. Therewith output spectra of the HF laser significantly widens and cascade laser action on some rotational lines of HF molecule vibrational transitions v(3-2) → v(2-1) → v(1-0) is observed. Specific output of the non-chain HF-laser over 8 J/l (140 J/l×atm) and total laser efficiency η_0~4,5% were achieved., as well.

4. Conclusion

It was shown that discharge parameters have strong effect on the HF laser output. Application of the inductive generator, electrodes of uniform field and intense preionization allows to form uniform volume discharge and improves intrinsic laser efficiency. Excitation modes with maximal intrinsic efficiency η_{in} =10% was realized using the capacitor and inductive generators. The use of the inductive generator allows to improve η_{in} in wide range of input electric energy (10 - 100 J/l). The generator provides breakdown electric field strength up to E_0/p = 200 kV/cm×atm and significant part of stored in the inductor energy is deposited into the laser active volume at high E/p value across the laser gap during short current pulse. The laser energy up to 1,4 J, specific output of 7 J/l and total laser efficiency over 3% were easily achieved.

Discharge uniformity, increase of the rate of fluorine atom formation in the laser active volume [4] and cascade laser action can explain high intrinsic efficiency of the discharge HF laser.

Maximal output up to 1.9 J and total laser efficiency η_0 = 4,5% were obtained in the SF_6-H_2-C_5H_{12} mixtures using the capacitor generator with low circuit inductance, electrodes of uniform field and intense preionization.

4. References

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